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ABSTRACT

Advantages of using the microcomputer as an interactive electronic blackboard are discussed, and programs and programming techniques are described to illustrate the construction, design, storage, and modification of colorful and animated graphic displays. The methods described are based on use of an Atari 800 microcomputer but could be used on other systems. Suggestions are made for the use of display lists, short programs dedicated to the video display, which specify where to find screen data and which mode and what special display options, if any, are to be used. Another technique explained is page flipping, a process which permits a number of different screens or pages to be drawn by a single computer program. The program is able to store the display list instruction set for each of the previous screens and rapidly recall them if desired. Descriptions of programs that use these methods include a summary of the main features of 11 specific programs developed by the author. Examples are given of programs for physics simulations, graphing and plotting, numerical problem solving, and the production, saving, and modification of diagrams. Sample uses are explained to show how the program might be employed by an instructor. A summary and four references are included. (LMM)

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CAI: PROGRAM AND PROGRAMMING TECHNIQUES THAT UTILIZE THE MICROCOMPUTER AS AN INTERACTIVE AUDIO-VISUAL DEVICE

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INTRODUCTION

The purpose of this paper is to discuss how a microcomputer can be used as an interactive electronic blackboard. (Software that the author has written will be presented at the conference to illustrate the points discussed.)

The programs and the programming techniques discussed are those that illustrate the construction, the design, the storage and the modification of the colorful and animated displays. A discussion of techniques that permit the drawing of diagrams directly on the video terminal are also included.

RATIONALE

Why write a paper that describes how a computer can be used as an interactive electronic blackboard? The reason is that the majority of instructors still teach standing at their blackboards; drawing, writing, and lecturing. A paper that discusses how these "Chalk and Talk"(1) teachers can effectively employ the microcomputer might therefore be of some use to these educators.

It is hoped the techniques described in this paper will prove interesting enough for other instructors to try. Because the methods require only a single computer--most teachers have access to at least one microcomputer--they should be able to be implemented immediately. Also, the computer and the programs could initially be shared among a number of different instructors. Using the computer in the manner described eases it into classroom use. This may overcome some of the reluctance that instructors have about using a computer as a teaching tool. This gradual introduction of the computer does not require the massive effort in time, money, material, or personnel that a CAI system demands.

Using the computer as a supplemental blackboard can accomplish a number of things. It can make the instructional process more effective by: reducing preparation time, increasing the student's understanding of difficult concepts, allowing more instructional time to be spent on learning rather than the production of blackboard diagrams, and by allowing the design, storage, modification, and evaluation of the major parts of a lesson. In this way a library of effective lessons can be achieved and maintained.

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THE COMPUTER

The methods described in this paper were produced using an Atari 800 (Atari is a registered trademark of Atari, Inc.) microcomputer. The total system consists of the computer (48k), a color monitor, a disk drive, and an Okidata 82A printer. The configuration described can be purchased for about $1500.

The Atari microcomputer was chosen for a number of reasons: its ability to create excellent graphic displays, its ease of cursor control, the variety of input/output (I/O) devices that can be used, and the four voice sound generator. The graphic displays are enhanced further by the presence of features that are usually found only in commercial arcade games. Commercial features such as player-missile graphics. The detection of player-missile collisions are useful when the computer is used to simulate the interaction of moving objects.

The variety and clarity of the Atari's screen displays were the deciding factors in selecting this computer. Creation of these displays is made possible by the fact that the computer has sixteen different display modes. From BASIC three text modes and six graphic modes can be accessed. Using machine language three new text modes and four new graphic modes can be used. Graphic modes up to a maximum resolution of 320 horizontal pixels and 192 vertical pixels are achievable.

The clarity of the Atari's screen displays is due to the fact that the Atari has freed its 6502 microprocessor from handling the screen displays. It has three special-purpose large-scale integrated (LSI) chips known as ANTIC, CTIA, and POKEY to perform this function.

The ANTIC microprocessor has an instruction set that is dedicated to controlling the television display. A program known as a display list is resident in this chip. The display list and accompanying data is written into the RAM by the 6502 microprocessor. ANTIC retrieves this information from the RAM using direct memory access and passes the translated instructions to the CTIA.

The CTIA is a television interface chip. It converts the digital signals from ANTIC into the signals that are sent to the television. It has some separate functions as well: the addition of color values, the player-missile graphics, and their collision detection.

The POKEY is a digital input/output chip. It handles the sound generation, the random number generation, the paddle and joystick inputs, and the requests from other peripherals.

Although the programming techniques that will be discussed where implemented on an Atari 800, most microcomputers can do the same things. Working under the assumption that discussing something is often all that is required to stimulate others to adapt the methods to their computer, the following techniques are presented.

PROGRAMMING TECHNIQUES

Display Lists

A display list is a short program dedicated to the video display. The display list specifies; where in the RAM the screen data is to be found, which of Atari's sixteen modes are to be used, and what special display options, if any, are to be used. The Atari display list is a little different than those in the PET, the TRS-80 or the Apple computers (PET, TRS-80, and Apple are trademarks of Commodore Business Machines, Tandy Corp., and Apple Computer, Inc., respectively). The PET and the TRS-80 have one mode, the Apple three and the Atari sixteen.

Six of the Atari's modes are used for printing text on the video terminal (screen) and the other ten are graphics modes, used for plotting points on the screen. Each of the graphics modes may or may not have a four line text window at the bottom of the screen. These homogeneous modes are called directly from BASIC or from a machine language subroutine. To interpose the different modes on one screen is a little more difficult but the results make the effort worthwhile.

The custom designing of display lists is permitted by the Atari microcomputer. The different modes can be interposed (mixed and matched so to speak) on the screen by writing a short subroutine and inserting it into the program. In this way a number of different, "windows", each with a special purpose can be placed on the screen at any one time. For example, the first window might contain two lines of large text, followed by a window with two lines of smaller print, next a window using any of the plotting modes, followed by a different plotting mode window. The number of permutations and combinations of the fourteen modes permits the creation of a large and diverse number of multi-purpose screen displays.

Teachers should immediately see the many uses for such a visual device. Diagrams or graphs that use titles and subtitles could easily be programmed. Illustrations that need sequenced diagrams and explanatory text can be handled quite easily. The drawing of two different resolution graphs on one screen can be accomplished using this technique. Sample programs which permit teachers to quickly custom design their own display lists will be demonstrated and made available to those who wish them.

Page Flipping

Page flipping is a name given to a process which permits a number of different screens (pages) to be drawn by a single computer program. The program is able to store the display list instruction set for each of the previous screens (pages) and rapidly recall them if desired. This ability to go from one screen to another is known as "page flipping". This is possible because the memory locations for the screen's display list can be moved around in the RAM. By allotting different locations for different screens, one can draw using a 48k computer, up to 30 screens containing text or three high resolution (320x192) screens. The technique of page flipping is analogous to a slide presentation. With the push of a button a new slide can be projected on the projector's screen. Using the computer's ability to page flip a new and colorful diagram can be placed on the video terminal with a push of a key. The beauty of the process is in the ease of producing, modifying, storing, and retrieving colorful and detailed diagrams.

Consider the possibilities. The computer spends minutes (or hours) drawing graphs or diagrams. Once drawn, they all can be saved on a floppy disc and recalled when they are required. Practising teachers should be able to invent may uses for such a system. The presentation and saving of: notes, illustrations for the favorite guest lecture, graphs, and portraits are just some of the many uses. More detailed techniques are outlined in the paragraphs below.

Adding new colors to a diagram can be accomplished by page flipping. Although the Atari microcomputer has sixteen colors each with sixteen luminances (shades) only sixteen different colors or one color with sixteen different luminances can be placed on the screen at any one time. If the screens are identical, except for their colors, then page flipping them produces an illusion of many new colors in the diagrams. The speed that the pages are flipped is only limited by how fast the screen is drawn (the screen on a television is drawn every 1/60 of second). The persistence of vision (1/15 second) indicates that up to four images can be overlapped on the screen without having too much flicker. In this manner one can produce diagrams on the screen that seem to use a large number of colors.

Page flipping can also be used to smoothly move very large objects across the screen. With a computer, animation of large objects is difficult to do, unless page flipping is used. The movement of lines across maps, the illustration of different occupied territories on a map, the display of diagrams from different angles, and the portrayal of three dimensional motion (depth motion on a screen) are all made possible by page flipping. This is a very powerful technique indeed!

Page flipping combined with customed designed display lists can produce spectacular looking screens.

THE PROGRAMS

The instructional programs that use the discussed methods are mainly limited to the following: physics simulations, graphing and plotting programs, numerical problem solving, and the production, saving, and modification of diagrams.

Some commercial software is used and has been very useful in providing the techniques for the drawing, the saving, and the modifying of the individual diagrams. These programs also provided the means for: the coloring of the individual diagrams ([2]), the creation of the special characters and the construction of new sets of fonts ([3]), and for the mixing of the text and diagrams ([4]). Most computers have software that can be used in similar manner.

The following programs are the programs developed by the author:

1. Simple Harmonic Motion
2. Millikan Experiment
3. Astronomy (Kepler's Laws)
4. Coupled Oscillators
5. Plotting Electric Fields
6. Three Body Problem
7. Ballistics
8. Motion in Polar Coordinates
9. Solving Differential Equations (Euler's Method)
10. Maxwell
11. Solving Univariable Equations

Rather than discuss the design characteristics in any specific program, the main features of all the programs will be summarized. The programs usually start with a portrait of the physicist responsible for the discussed concept. This produces a chance to discuss some history and the rationale for the work covered in the program. A display list section, that uses a combination of text and plotting modes usually follows the opening portrait. This portion provides a summary of the program functions and explains how the program is to be used. Finally, the main section is presented. This section performs the most important task of the program, the physics simulation, the graphing, the "number crunching", etc.

As an example consider the program, "Maxwell". It starts with a portrait of the man, James Clerk Maxwell, followed by a screen showing his famous equations, and then by the main program that demonstrates time-lapse diagrams of a moving three dimensional electro-magnetic wave.

USES

Programs such as the ones listed are designed to be used by instructors, especially if they prefer more traditional teaching formats. Although the programs can play the same role as a film, a film loop, or a slide presentation; they can do much more. Some of the programs permit the instructor, by changing the controlling parameters, to demonstrate a variety of physical and experimental behavior. Used in conjunction with actual demonstrations they permit the unification of the theory and the actual physical event. Others are used mainly to illustrate difficult concepts. Some just show that the mathematical descriptions correctly predict the assumed behavior. The programs on numerical analysis permit the instructor to assign and do problems that either have no mathematical solutions or are too time consuming to attempt. Once the students see what the programs can do they may ask to use them to explore their own particular problems.

Some sample uses are described in the paragraphs below. These examples are not meant to be complete, but only to show how the program might be employed by an instructor.

The simulation program, "Simple Harmonic Motion", allows the instructor to explore damped harmonic motion. The program not only shows what happens when the damping constant is changed; it draws a graph of the resulting motion. To be able to physically "see" both the motion and the plot is instructive. It is fascinating to actually set up apparatus to demonstrate the validity of the predicted motion. The plotted graph can be analysed to find the frequency and the damping constant.

Other programs, "Millikan" for example, can be used solely as a class demonstration to show how the quantization of electric charge was discovered. It permits the whole class to see what is happening inside the apparatus. The program enables the instructor to explain the observed behavior. Data can then be recorded and analysed.

The program, "Solving Univariable Equations", enables the user to input an equation and lets the program "solve" it by using a trial and error technique. A numerical solution is printed, if there is one. This program should provide the means for an instructor to assign problems that require the students to only set up an equation. It does not require that the students have the ability to solve it. Once the students have reached this final step of writing the equation, they can test the validity of the equation by running the program to see if it gives a reasonable numerical answer. In physics, this type of problem and this method of solving it, play an important role but is often ignored at the undergraduate level.

SUMMARY

Choosing the concepts that are to be taught by this computer assisted technique is not difficult to do. Look for topics, concepts, problems that are time consuming to teach. The production of complex and elaborate diagrams that would normally be drawn on the blackboard, can be done on the computer before the lesson. Concepts that have to be covered many times during a semester are candidates for such a process. Through this process, and as the years pass, more and more programs can be added to the instructional library.

Even though some programs will have to be modified and others will be rejected as unsatisfactory, the computer will have become an integral and indispensable part of the instructor's lesson plan. This must be one of the major goals of this paper. Some of the other goals might be the following: the improvement of the instructional process, the demonstration of the practicality of using computers in the classroom, overcoming the natural reluctance of most teachers for using computers, and proselytizing its use to other instructors, especially in fields other than the sciences.

The author encourages those that are interested in acquiring the programs or those who wish to discuss these and other techniques to contact him at the following address:

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